



Marine Monitoring Handbook

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Procedural Guideline No. 3-10

Sampling marine benthos using suction samplers

Dale M. Rostron, Subsea Survey¹

Background

Airlift suction pipes have often been used by archaeologists to excavate sand and silt from ancient wrecks (Cousteau and Roghi, quoted by Flemming, 1962) and by civil engineers. However, suction samplers have a history of spasmodic usage in marine biology. Examples include:

- baseline information from SAC sub-features, e.g. seagrass beds, maerl beds (Falmouth, Rostron 1985); shallow areas in the Harbours Rias and Estuaries surveys (Rostron 1987, Hiscock 1986); Isles of Scilly (Rostron 1983); Scottish Sea Loch Surveys (e.g. Howson 1991, Davies and Connor 1993)
- local pollution studies (Whiteness Voe, Rostron 1989)
- zonation studies of sublittoral cryptofauna on rock (Lundy), and population/quantitative sampling studies (Hiscock and Rostron, unpublished; Rostron 1983).
- complement to visual or photographic studies (Gulliksen 1980; Rostron 1996)

History of Use

Brett (1964) described a portable diver-operated hydraulic sampler which produced suction by the aspirator principle using a jet of water from a portable pump. The dredge was used to suck animals and plants from within a steel frame of known area, 15cm deep and driven into the sediment by hand. But this device did not work satisfactorily on some hard-packed sands.

A solution to these difficulties was the use of an airlift pump. Water and sample material are pulled through the sampler by the force of the rising low density air/water mixture in a vertical pipe. Barnett and Hardy (1967) designed an airlift sampler in two parts (Figure 1). The first part was a cylinder which was pushed into the sand to enclose a known surface area to a known depth. The second part was a suction pump used to excavate and sieve the sand and animals from within the cylinder.

Hiscock and Hoare (1973) modified the Barnett and Hardy sampler for use on hard bottoms (Figure 2). They required a portable system, with sufficient suction to prevent detached species from falling or being swept away, and the possibility of taking several samples which could be easily removed from the apparatus. Lead weights were fixed to the suction chamber end of the unit to prevent buoyancy during operation, and 3m of wire-wound flexible tube was used for suction as this was found to be easier to transport than rigid tubing. This sampler is not generally suitable for sediments because of the limited capacity of the sample chamber.

Gulliksen and Deras (1975) constructed a diver-operated suction sampler for fauna on rocky bottoms (Figure 3). It consisted of a sampling bottle with a 0.5mm sieve connected to a manual suction pump. This sampler was suitable for sampling sediment and smaller sessile fauna, and several samples could be obtained in storable plastic bottles during one dive. Gulliksen (1980) used this sampler during investigations of the macrobenthos in Borgenfjord, Norway.

A more recent design (bucket sampler) based on the Hiscock and Hoare machine (Figure 4) incorporates a larger sample chamber and can be used on sediment. However, periodic emptying of the sample chamber is necessary if several samples are collected.

The most recent design (by J. Woolford) is a miniaturised airlift sampler (Figure 5) known as the JW Miniature. This uses a pony cylinder which can be attached to the diver's main cylinder, and an on/off

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switch more normally associated with diver direct feed systems. Copper tubing is used to provide the air supply to the inside of the 5.5cm diameter plastic pipe. The sampler is 52.5cm long overall, with a small lead weight attached 12cm from the bottom for stability. There is no collection chamber and material is deposited into a detachable bag. The system is very light, enabling the diver to swim to the required station before sampling.

Summary matrix

<i>Substratum</i>	Steep gradient	Rock	Mixed substrata with stones	Coarse gravel	Maerl	Medium fine sand	Muddy Gravel	Mud
Barnett and Hardy	✗	✗	✗	✓	✓	✓	✓	✗
Hiscock and Hoare	✓	✓	✗	✗	✓*	✓	✓	✗
Bucket type	✓	✓	✓*	✓*	✓*	✓	✓	✓
JW miniature	✓	✓	✗	✗	✗	✓	✓	✓

* Care must be taken not to exceed the capacity of the sample container.

Purpose

It is clear that non-destructive *in situ* techniques observe only those species which are large and/or prominent on the substratum, and that the true range of species present within a biotope cannot be investigated by these methods. Many of these larger species are fairly ubiquitous, and may not be sensitive to environmental changes. Pollution studies have often shown the sensitivity of smaller animals, such as amphipods, to adverse environmental change and suction sampling will capture these.

For sediment biotopes, the principle of grab sampling, a destructive technique, is well established. On sediment, suction sampling offers a smaller scale, possibly more objective way of achieving the same results. It is also useful for collecting baseline information from small areas.

In the rocky sublittoral, the principle of destructive sampling is not encouraged and much emphasis has been placed on non-destructive methods. However, previous comparative studies (Gulliksen 1980, Hiscock and Rostron, unpublished) have shown that the majority of the biota is not recorded by such methods. Suction sampling, on a very small scale, would therefore provide good baseline information and a fuller appreciation of the communities monitored.

Suction sampling can be used as a monitoring technique in cases where other methods are not appropriate; for example on coarse or mixed substrata. It is also a thorough technique for delineated biotopes such as maerl beds. It is most economically used for 'whole community' information, but at the same time could provide important population statistics for 'potential key species'. However, in view of the large volume of sample material and the time needed for sorting this, it is not a suitable method in cases where, for example, only a few key species are monitored.

In summary, suction sampling can:

- be a good technique to use prior to deciding on a final monitoring programme or key species to be monitored. It provides baseline information, particularly about biodiversity, interesting biotopes or sub features.
- be useful to check the overall health of specific communities/biotopes, e.g. maerl beds, muddy gravel.
- be used to establish/re-establish the species which are present in a biotope.
- provide comparative numerical data for regular or relatively large scale studies.

Advantages

- Fully portable apparatus. Ease of deployment depends on the model used.
- Personnel need only brief instructions to use the sampler, which is not technically difficult.
- The exact habitat conditions at the site can be recorded, e.g. phase 2 recording for rocky substrata. Sediment data can be collected from exactly the same location as the biota, often a hit and miss affair with grabs, which must be deployed more than once.
- Samplers can be deployed from a small boat. Thus divers can sample in areas which may be inaccessible for larger vessels deploying grabs, e.g. Whiteness Voe, Scilly (Rostron, 1989). Small-scale surveys can be undertaken

- Sampling efficiency is high. Christie (1976) found that on fine sand 40% of the species present to 60cm depth occurred deeper than 10cm. Keegan and Konnecker (1973) found that on maerl substratum as much as 98% of the standing crop may be found 20–40cm below the surface of the substrate. Suction samplers can reach these depths if required.
- Suction sampling methodologies are complementary to other non-destructive techniques such as photography or quadrat studies.
- Samples which are difficult to collect by other means can be obtained. Coarse substrata such as gravel and stones can be collected. Algae and sessile organisms on rock can be collected quantitatively.
- Samplers can be used for varied types of seabed, and different mesh sizes can be easily inserted if needed. Different surface area samples can be taken.
- None of the material removed from the rock is lost and almost all of the biomass is collected.
- Counting and abundance assessments are possible. Robust statistical methodologies can be used, such as parametrics or multivariate classification techniques, etc.
- Samplers can be constructed from cheap and readily available material with minimal machining.

Disadvantages

- It can be expensive using divers to sample relatively small areas.
- Depth and number of samples are limited by the diver's capabilities. In addition, samplers will not work at depths less than the length of the suction tubes.
- Samplers are efficient at deeper levels, but require a greater supply of air to maintain the same suction pressure.
- It is sometimes difficult to fill machines with water for descent and to carry them down, especially in rough surface conditions. Deployment requires considerable skill. Too much buoyancy in the chamber when air is introduced for sampling can cause some samplers to rise.
- Large specimens on rock may need to be removed before using the sampler.
- Strong suction and scraping can damage fragile biological specimens. Sessile tube-dwelling species and barnacles can be difficult to collect.
- It is not usually possible to see the accumulating sample material. Large samples may overflow the bags. The British Antarctic Survey designed a sampler similar to that of Hiscock and Hoare, but with a clear perspex tube which allowed one to see the quantity within the sample bag inside, and also other modifications to make the machine more suitable for very low temperatures.
- It can be difficult to extract samples from some sample bags.
- Laboratory time for sorting samples from sublittoral rocky bottoms is very high. Gulliksen (1980) intended to sort material alive, but found that some samples needed up to 10 days of concentrated sorting. Hiscock (1987) estimated that each 0.1m² sample took 5 days to sort and count, and this did not include the identification of all species.

Logistics

Equipment

Boat, plus diving, navigation and safety equipment, as required for normal diving operations under the HSE regulations. An echo-sounder is essential in cases where the seabed conditions are not known. Buoyancy aids and rope are also required: the latter may be needed to retrieve the sampler from the seabed by hauling it from a support vessel.

Sampling equipment, scraper, spare sampling bags and lids, quadrats, spare air cylinders. The area which can be sampled with one cylinder of air will depend on the amount and type of material being collected, the depth, and the suction applied. Hiscock and Hoare (1973) took three 0.25m² samples at 15m with a 1.6m³ cylinder.

Quadrat shape may vary, with deep cylindrical shapes suitable for sediment and more usual square shallow designs for rock. Workers need writing boards and sample carrying equipment on the seabed. Numerous sample bags are heavy and unwieldy to transport, and could be fixed to a line buoyed at the surface (Figure 6).

Buckets for surface storage, one or two per sample. Sieves, reliable labels, such as DymoTM and preserving fluids.

Personnel/time

Minimum HSE diving team (4 divers) plus possible additional boat staff. The divers must have appropriate qualifications (Holt 1998).

Methods

Site location

Latitude and longitude for sample sites must be determined accurately, especially if repeated monitoring work is anticipated. When using the Geographical Positioning System, the correct datum should be employed (WGS84 or OSGB, etc.) with quality control checks taken from known positions. In nearshore areas, prominent coastal and seabed features may also be useful for accurate relocation of sample sites.

Deployment

Once the correct position and depth have been located, those samplers with chambers need to be immersed until the air in the chamber is replaced by seawater, resulting in negative buoyancy. The equipment may be lowered by means of a buoyed rope, or alternatively transported to the seabed by divers. Additional equipment, such as spare bags and quadrats, may be easily lost if not assigned to a specific worker. It is therefore a good idea to discuss which diver will perform the various operations prior to their descent.

Field sampling

The Barnett and Hardy type of airlift design (Figure 1)

This sampler has no chamber and is easy to submerge. The 0.1m² cylinder is placed on the seabed and pushed a few centimetres into the sediment by hand. For deep samples, the lid is secured by means of four clamps. The air supply to the airlift pump is then turned on slowly and water pumped out of the cylinder. The head of water above the lid forces the cylinder into the sand and penetration of the cylinder to a depth of 60cm usually takes about five minutes, after which the clamps are released, lid removed and sand inside removed by the second part of the sampler.

In practice, it is often possible to manually work a cylindrical quadrat into the sediment by holding the handles and rotating rapidly in clockwise and anticlockwise directions.

The sampler has a long rigid pipe with an internal diameter of 8cm, weighted at one end. It can be very difficult to manoeuvre and hold this sampler in a vertical position, which means that it cannot be utilised when tidal streams are present. The air supply is turned on slowly until there is a rapid flow of water up the suction pipe. The suction tube is then directed towards the substratum, within the quadrat. The sampled material is caught in a mesh bag, but the silt and sand may descend onto the divers, making sampling difficult.

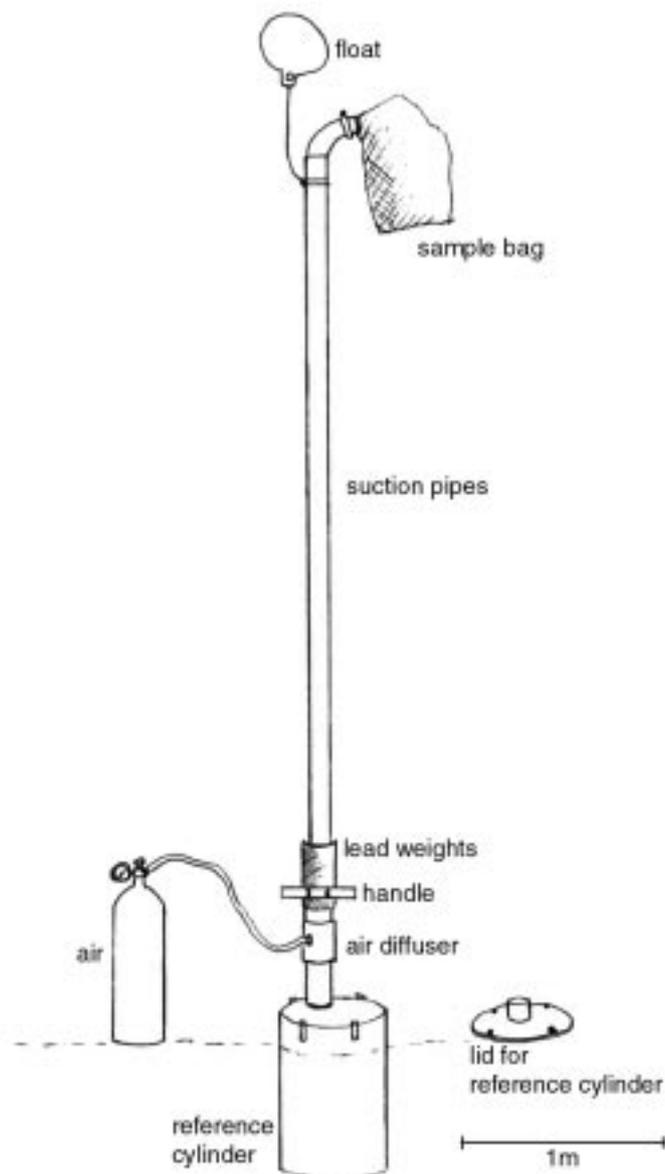


Figure 1 The Barnett and Hardy (1967) type of sampler

The Hiscock and Hoare type of airlift design (Figure 2)

The divers enter the water and inflate their buoyancy control devices. The sampler is handed to a diver, who allows it to fill with water before adjusting buoyancy to submerge. Supplementary equipment (quadrats, tubing, etc.) is taken to the seabed by the other diver.

The sampler is assembled on the seabed and placed appropriately on the bottom; the quadrat is then put in place. Large specimens liable to clog the tube are removed for later inclusion in the sample. This is done by means of a paint scraper used to detach the organism carefully from the rock. Tubing is unwrapped and the float carries the suction tube to a vertical position. The air supply is turned on at the pillar valve to create the necessary suction. The paint scraper is used in front of the collecting tube to dislodge organisms within the quadrat. When the quadrat is cleared, the air supply is increased for a few seconds to draw any material left in the collecting tube into the sample chamber. When the sample has been taken, the number of barnacle or tube worm scars can be counted or the site photographed for later counting or measurements of percentage cover. The sample bag is removed and capped and another bag is screwed in place ready for the next sample. If a buoyed line has been tied to the sampler, the apparatus can be pulled to the surface after removing all loose parts.

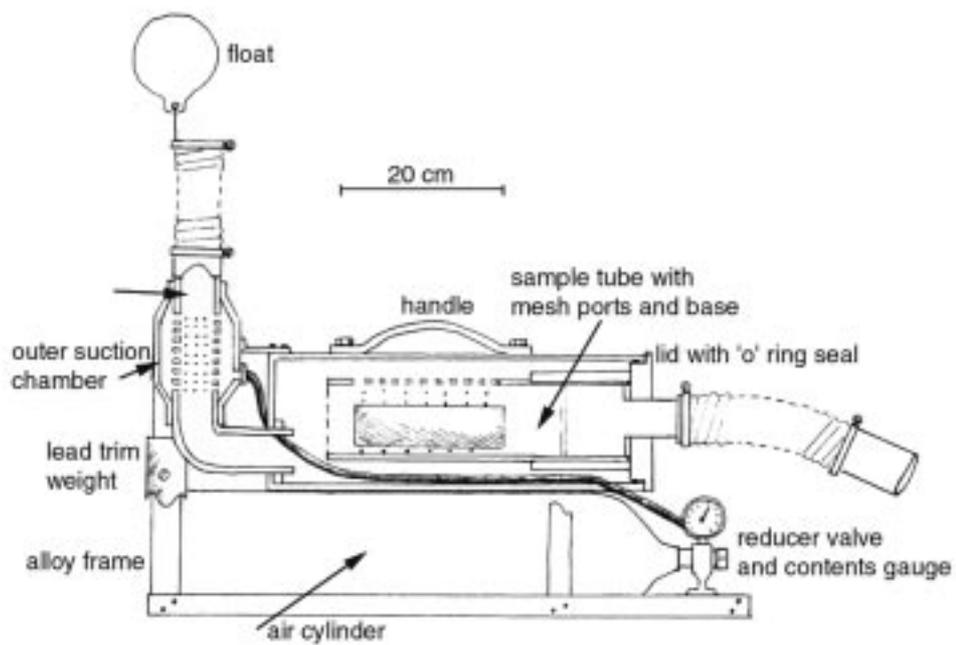


Figure 2 The Hiscock and Hoare (1973) sampler

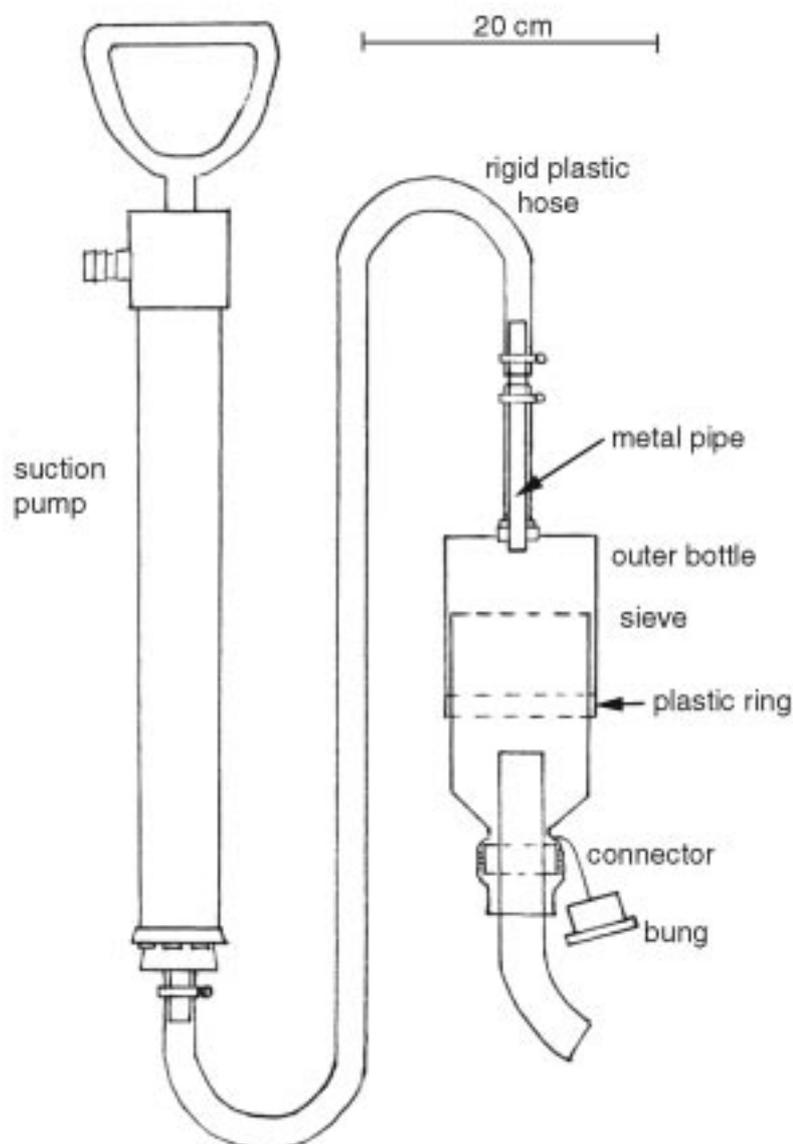


Figure 3 The Gulliksen and Deras (1975) sampler

The bucket sampler (Figure 4)

The tubing is attached before deployment. This sampler has a large chamber, and takes several minutes to fill with water. This is generally achieved by undoing two of the clips on the lid, holding beneath the surface, and then re-fastening the clips before descent. Lead weight can be placed into the chamber, but this makes the sampler heavier for retrieval. It is a good idea to save underwater time by fixing the first sample bag before descent. The air supply should be connected at the surface, although bottles can be exchanged underwater if necessary. The sampler is attached to a buoyed rope.

Once on the seabed, the quadrat is placed by whatever means are appropriate. Suction is quite powerful, and can result in positive buoyancy and shifting of the machine if the air is turned on too quickly. One diver concentrates on the air supply and sampler, whilst the other positions the suction tube inside the marked quadrat. Communication and co-ordination between the two are needed. At the end of the first sample, the suction tube should be held upwards to avoid loss, the air must be turned off, the lid opened and the bag replaced. Sediment accumulated in the bottom of the chamber should be emptied. The screw thread attaching the bags can take some time to deal with, but does ensure that the bags are firmly fixed and can hold large samples, including stones. Filled bags should have a screw cap.

This sampler, particularly if it contains sediment, is too heavy for easy transport to the surface and divers should ascend the line carrying the loose equipment. The sampler may be pulled to the surface later.

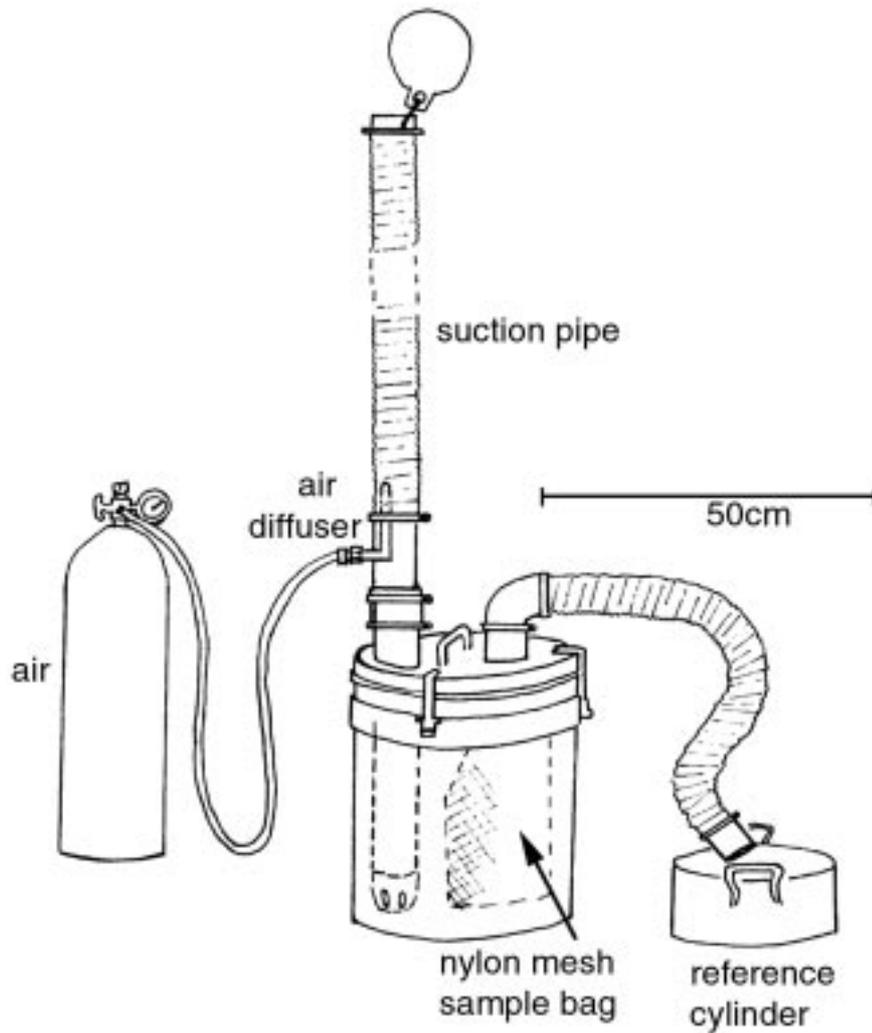


Figure 4 The bucket airlift with a large sample chamber (Hiscock 1987)

J. Woolford rock epifauna sampler design (Figure 5)

The air supply, a pony cylinder, is fixed upside down to the diver's main cylinder, in order to make the valve accessible. The air supply is attached to the direct feed on the sampler which in turn may be attached to the diver by means of a line and clip. The quadrat, scraper, nets and flexible tubing can be carried down separately and attached at the seabed. The tube is curved and fits over the diver's shoulder, so that any silt disturbed does not interfere with the sampling procedure. The quadrat is placed, and the diver is able to scrape with one hand and use the airlift with the other. Pushing the button on the direct feed regulates the air supply. Alternatively, a second diver may assist.

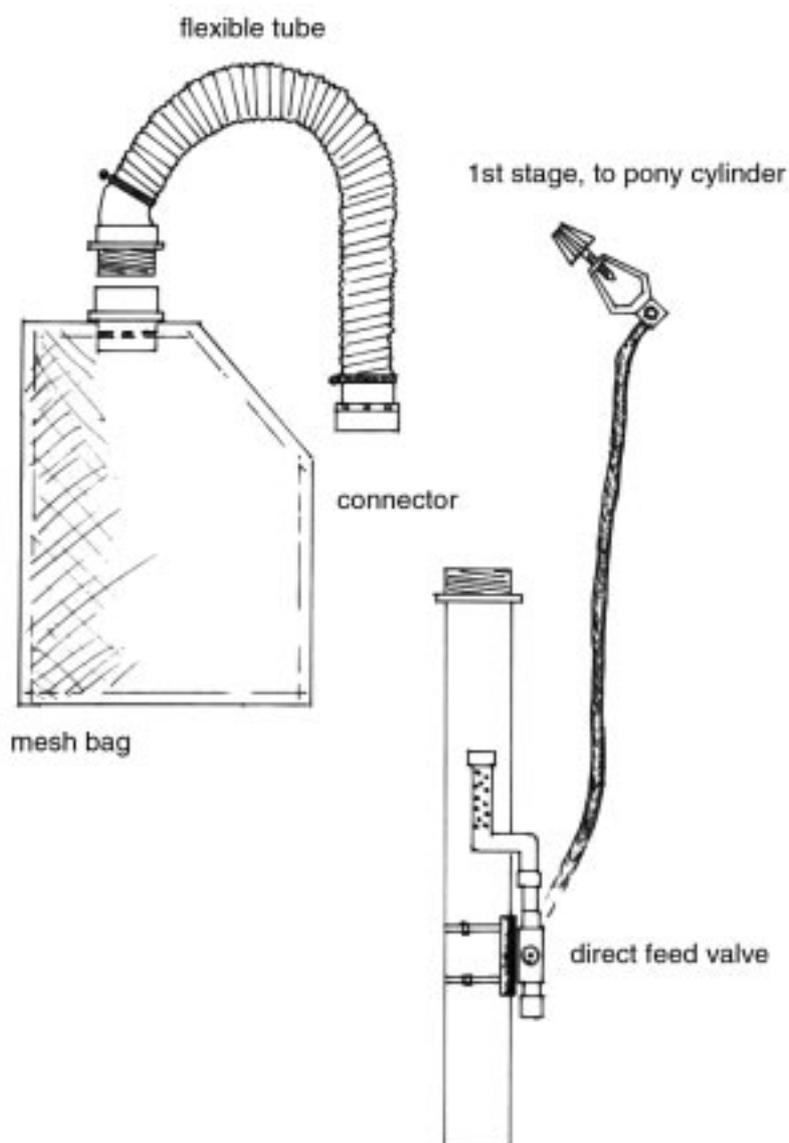


Figure 5 The JW sampler (original drawing)

Substratum and mesh size

Normal mesh sizes are 1mm and 0.5mm and the client should specify the size required. When sampling a benthos of gravel, stones or mixed substrata, most will be retained within either mesh and the limiting factor is the bag/chamber size. The grain size of coarse sand may be between 0.5mm and 1mm. In this case, for efficient sampling, it would be more practical to use the larger mesh size. Finer sands and muds should all pass through the 0.5mm mesh.

In situ observations

If time allows, in situ observations detailing depth, habitat type, sediment structure, etc. should be recorded. It may be appropriate to record abundances of colonial species at sample sites using a SAC-FOR scale, particularly if sampling from rock.

Retrieval of sample equipment

Divers may have difficulty in retrieving samplers from the seabed if:

- the sample site is >15m deep
- full sample bags, spare cylinders or other heavy items need to be attached
- a sample chamber (bucket sampler) is full of sediment
- tidal currents are present
- divers are carrying surface marker buoys
- visibility is bad or sea surface conditions are adverse

For these reasons it is safer to use an attached line for retrieval from the boat, once the divers are safely on board. All detachable parts should be securely fixed to avoid loss. However, these considerations do not apply to the JW miniaturised sampler, which is carried by the diver.

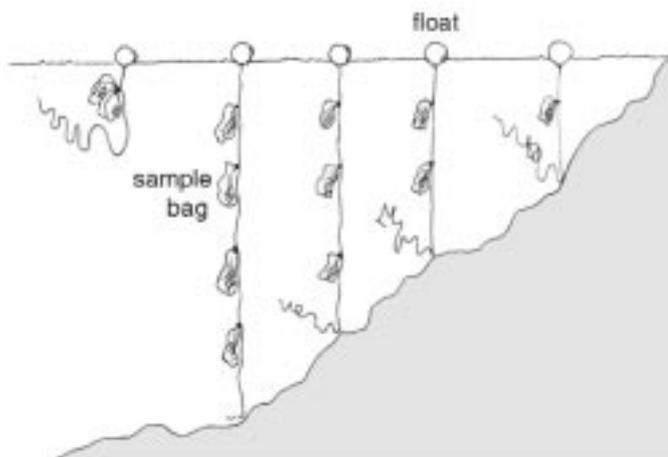


Figure 6 A method for retrieving samples

Sample storage and labelling

On the boat, sample bags should initially be placed in buckets containing seawater and labels. The latter should be made of plastic paper and cross-referenced to any numbering system or in situ notes recorded underwater by the divers. It should not be necessary to empty sample bags at this stage.

Once on shore, sample bags are emptied into individual containers containing seawater: they may need to be quite large. The bags are made of tough nylon mesh and access is provided through a Velcro™ fastening. Some material may be difficult to get out, but care should be taken not to damage organisms. One method is to use a large spoon to remove much of the material, before inverting the bag and rinsing material off the mesh by immersing in seawater. Each sample may then be sieved and placed in preserving fluid along with an appropriate label.

Laboratory

Adequate wet facilities including a fume cupboard for processing samples are required, along with bench space for binocular and compound microscopes and all appropriate taxonomic keys and guides.

For rock samples, quantitative and qualitative material is separated before identification and counting, or abundance estimates. Because the volume of material can be large it is useful to initially sort into taxa, such as amphipods, algae, prosobranchs, polychaetes, bryozoa, etc. From here, the fauna and flora should be identified to species level whenever possible and a list of taxa compiled. Taxa should be listed according to a recognised authority (Howson and Picton 1997). Individual animals may be counted. Colonial animals and algae must be assessed by other means, e.g. by *in situ* diver observation at the sample sites. In the laboratory, a more subjective estimate of the probable surface area % of the species within the sample would provide a comparative measure.

Procedures for mixed samples such as pebbles/mud or maerl may be similar to the above.

For sediment samples, sorting, identification and enumeration procedures are well established. Voucher specimens should be kept separately and properly labelled.

Data analysis

Data generated should be stored on a spreadsheet or database from where it is accessible for computer analyses. Data analysis depends on the initial objective of the suction sampling programme.

Accuracy

Objectives should be clearly set out before suction samples are taken. For repeat surveys of sediment areas, it is essential to accurately relocate sample positions according to established protocols. The type of sampler should be appropriate for the work undertaken. In sediment or loose mixed substrata, there is always a temptation to take samples to a deeper level than necessary which should be avoided by using quadrats of the appropriate shape, depth and width.

Replication is not a desired option when using a suction sampler at deeper sites because of the time implications, the size of the samples and also the fact that working conditions (visibility) could be compromised by repeated sampling at one locality. Cost may limit the number of localities sampled.

In rocky sublittoral areas, the heterogeneity of the environment means that the provision of statistically useful data for repeat monitoring over a large area cannot be expected. Data should not be over-interpreted.

Unless there is a sufficiently large number of samples, great care should be taken when making sample comparisons between:

- one year and another (temporal)
- one depth/place and another for a particular biotope (spatial)
- widely spaced samples from the same area (spatial)

QA/QC

- Well-defined objectives should be set before employing this methodology.
- An equipment inventory should be checked before leaving the shore.
- Boat personnel should be able to locate the survey station precisely from the position of the surface buoy and be able to retrieve the sampler and other items by hauling from the seabed.
- There should be standard, appropriate quadrat sizes and general agreement on depth to be sampled.
- Divers should be familiar with equipment to be used. Operators should be able to collect standard samples, adequately describe the site, habitat and larger biota, ensure that the sample chamber does not overflow, clear any tube blockages, and take care not to lose material during bag changing or by turning off the air too soon.
- Samples must not get confused either underwater or on the surface.
- Samples should be handled so that minimal damage is done to biota, e.g. do not swing bags around in air; always support in water.
- It is essential to be realistic about the laboratory time necessary for sample processing.

Data products

- New information in many cases
- Detailed data matrix – stored as a spreadsheet
- Collection of specimens

Cost and time

Field

Using a team of 4 divers (2 pairs) on a schedule of two dives per day, it would be possible to obtain between 8 and 16 samples depending on the depth, underwater conditions and type of habitat to be sampled. (Sandy sediments are easier than rock epifauna.)

Laboratory

The laboratory time may also vary significantly depending on the sample type collected. Sorting a large sample takes between 1 and 3 days, whilst accurate identification and enumeration takes 3 to 5 days. The times involved are long because suction samples from sediment are larger than grab samples of the same surface area, whilst samples of rock epifauna and associated cryptofauna are extremely diverse, with identification complicated by the fact that many organisms are epiphytic on others. Costs for a 15cm deep, 0.1m² sample may vary from £800 for an interesting sediment sample with 30+ taxa to c. £1,500 for a detailed analysis of the same area rock epifaunal sample taken from a diverse circalittoral turf.

Data analysis

Given an accurate spreadsheet from the laboratory work, computerised data analysis techniques take relatively little time, probably about 1 day.

Health and safety

All diving operations are subject to the procedures described in the Diving at Work Regulations 1997² and must follow the Scientific and Archaeological Approved Code of Practice.³

A minimum team size should be specified.

Buoyancy (both positive and negative) of the equipment and accumulated sample material is a problem and must be addressed in the risk assessment.

Additional risk assessments are needed for certain areas such as tideswept sites.

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2 The Diving at Work Regulations 1997 SI 1997/2776. The Stationery Office 1997. ISBN 0 11 065170 7
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3 Scientific and Archaeological diving projects: The Diving at Work Regulations 1997. Approved Code of Practice and Guidance – L107. HSE Books 1998. ISBN 0 7176 1498 0.
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